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Design information release under alternative design-construction modes

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Abstract

Purpose – The purpose of this paper is to analyse the impact of schedule compression under alternative project delivery methods (APDMs) on the design information release (DIR). The objectives are to understand the dynamics and the respective implications of the DIR under alternative design-construction (DC) modes (e.g. fast-track).

Design/methodology/approach – The methodology of work includes: (1) identifying the relevant factors that may impact the release of design deliverables under APDMs, (2) representing the selected APDMs with corresponding DC sequencing modes and (3) conceptualizing the possible alternative dynamics of the released deliverables.

Findings – The findings reveal that in contrast to the traditional one-time packaging of design deliverables, multiple DIR – with less certainty on their scope, timing, frequency and coordination quality – are released under alternative DC modes. This uncertainty mainly emanates from the deduced impact of the identified factors (e.g. DC overlapping intensity and degree of pressure by the builder) on the design deliverables dynamics.

Practical implications – This study can be of benefit to Architecture/Engineering (A/E) professionals as well as to project owners in better planning for their roles and responsibilities under each of the identified modes, as it helps raising their awareness on new issues brought about by APDMs. For instance, the presented analysis indirectly informs designers, design review professionals and project owners about a potentially increased liability exposure emanating from the reduced certainty on the DIR's coordination quality. Moreover, it informs design managers about the need for a design team's re-formation and/or re-structuring (i.e. of the involved staff) in order to accommodate for the hypothesized DIR dynamics.

Originality/value – This work offers a novel study that theorizes the impact of time-reduction-related factors, under alternative DC modes, on the release of design deliverables.

Keywords Project delivery methods, Design-construction overlap, Fast-track, Design deliverables packaging

Paper type Research paper

Introduction

Several alternatives to the lengthy process of the traditional design-bid-build (DBB) delivery method have evolved over the years to suit the increasing needs and complexities of the construction industry. Owners opt for alternative project delivery methods (APDMs) for the main reason of compressing the project schedule, i.e. reducing the overall project delivery time, (Lopez Del Puerto *et al.*, 2008, Culp, 2011; Touran *et al.*, 2011; Sullivan *et al.*, 2017; Antoine *et al.*, 2019) or delivering projects at a more intense pace (Antoine *et al.*, 2019). A plethora of scholars studied the comparison of APDMs performance in respect of the project cost, time and quality achieved. For instance, Sullivan *et al.* (2017) analysed two decades of APDMs literature [namely, the design-build (DB) and the construction manager at-risk (CMAR)] in various project types (e.g. transportation, buildings, military projects, etc.). Their findings

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revealed that both CMAR and DB relatively controlled the schedule variation of a project, in comparison to the DBB, and DB provided the highest delivery speed across all the explored studies (Sullivan *et al.*, 2017). Similarly, Chini *et al.* (2018) found that the greatest advantage of DB is the timesaving it offers, since it entails a faster delivery speed as well as a faster construction speed. El Asmar and Ariaratnam (2018) analysed the performance of APDMs for water and wastewater infrastructure projects. The authors found that the DBB had the slowest project delivery speed (i.e. how fast a project is being designed and constructed in relation to its size), defeated by the CMAR, with the DB presenting the best speed performance (El Asmar and Ariaratnam, 2018).

The potential timesaving advantage under APDMs is attributed to (1) having design and construction overlapped, as compared to the DBB in which a full design completion is needed before starting construction and (2) the cooperation between the designer and the builder (Touran *et al.*, 2011; El Asmar and Ariaratnam, 2018). Moreover, it is argued that the project schedule in CMAR is compressed to a more modest degree than in DB, because in DB (1) the degree of overlap is more pronounced since design and construction are obtained from a single entity (Touran *et al.*, 2011) and (2) less detailed documentation is required (Quatman and Dhar, 2003; Culp, 2011).

That said, schedule compression under APDMs is well established in the literature and is mainly realized by way of overlapping the design and construction phases. On the one hand, different degrees of overlap may be obtained under various APDMs, depending on the characteristics of each method. On the other hand, starting construction with partially completed design increases the uncertainty and complexity associated with the design work (Lee *et al.*, 2005; Zerjav *et al.*, 2011; Deshpande *et al.*, 2012) and leads to a higher frequency of rework (Moazzami *et al.*, 2011). To this end, several methodologies have been proposed in order to gain maximum advantages of the overlapping mechanism and minimize design and/or construction rework (Pena-Mora and Li, 2001; Bogus *et al.*, 2006, 2011; Hossain *et al.*, 2012; Khoueiry *et al.*, 2013; Srour *et al.*, 2013; Dehghan *et al.*, 2015; Hossain and Chua, 2014; Dehghan and Ruwnapura, 2014). For instance, optimization approaches that incorporate the concepts of upstream design evolution and downstream (i.e. construction work) sensitivity criteria were developed to optimize the project schedule while maintaining minimum rework (Khoueiry *et al.*, 2013; Hossain and Chua, 2014). Alternatively, other studies were limited to the design phase, thereby focussing on the overlap between design activities using dependency information or the concept of downstream design sensitivity to upstream design evolution (Bogus *et al.*, 2006, 2011; Hossain *et al.*, 2012; Srour *et al.*, 2013; Dehghan and Ruwnapura, 2014). The previously listed studies looked at the overlap either between design and construction activities/tasks or within design activities/tasks. While some do refer to fast-track projects (reflecting a general case of design and construction being overlapped/fast-tracked), none of these studies is applied in the context of a specific APDM. Namely, the features that characterize APDMs were not previously discussed in literature work addressing the overlapping mechanism. This study, distinctly, aims to investigate the impact of schedule compression and the respective overlapping of design stages under APDMs on the release of design deliverables. This is mainly achieved by conceptualizing the possible alternative design information release (DIR) dynamics, and then benchmarking these dynamics against the well-established release of design deliverables under the sequential design-construction (DC) mode of the DBB method. To that end, this research does not compare the advantages/disadvantages of the selected APDMs, neither advocates the use of a method over the other. Rather, the specific focus with respect to each of the considered APDMs is on the characteristics that allow these methods to be presented through alternative DC modes (as compared to the sequential mode of the DBB method). Furthermore, to be noted is that a comparison of the advantages/disadvantages of the delivery methods rather happens in terms of owners' suitability of a selected method given the set of prevailing circumstances (Al Khalil, 2002). Namely, the decision-making process of projects' owners/developers with respect to the most appropriate delivery approach for a project in question is affected by the project characteristics (e.g. clarity of scope, schedule, complexity, contract pricing), owner's needs (e.g. constructability studies; value engineering studies; contract packaging and feasibility studies) and owner's preferences (design responsibility, design control, owner's involvement after the contract's award).

Design services under standard forms of agreements

Standard forms of architecture and engineering services are offered by many organizations [e.g. the American Institute of Architects (AIA), the Royal Institute of British Architects (RIBA)] in order to define, amongst other services, the scope of the design services to be provided, the different design stages, the expected design deliverables, and the role of the A/E professional according to these stages. Despite the different terminologies that are used to define the design stages, standard forms of agreements are found to include the same core description of these stages and support the argument that design information matures progressively with an increasing level of detail in design deliverables. Therefore, design stages are observed as milestones to track the progression of the design process. This paper adopts the terminologies used by the AIA. Therefore, schematic design (SD), design development (DD) and construction documentation (CD) are regarded as the fundamental and logical design stages expected from the Architect/Engineer (A/E) to carry-out sequentially under a traditional design process.

As for APDMs, the AIA acknowledges the benefits, as well as the risks, stemming from the use of phased or fast-track schedules (American Institute of Architects (AIA), 2009; 2014a). These risks (as listed in AIA-B132 § 5.4.1 and AIA-B133 § 5.4.1) include the incurred additional costs to revise, re-coordinate, redesign and reconstruct portions of the work (American Institute of Architects (AIA), 2009; 2014a). However, there is no direct indication as to the mode of concurrency of design stages. On the other hand, the RIBA plan of work (2007) illustrates the possible sequencing of stages for the various PDMs. For instance, "a fully designed project single stage tender" (i.e. the traditional method), is illustrated by sequential design stages and sequential design and construction phases. As for the considered APDMs, design and construction phases become overlapped and the design stages become overlapped as well. As for the RIBA's 2013 version, it highlights that the procurement method in place dictates the nature of the overlap/concurrency of design stages and of information exchanges at a stage completion (Royal Institute of British Architects (RIBA), 2013).

Research design and methods

In order to investigate the research question, i.e. how schedule compression under APDMs may impact the release of design deliverables, three main research stages were performed followed by a discussion of the practical implications of the study findings, as illustrated in the research design roadmap (Figure 1). At a high level, this figure shows the activities that were developed at each stage, along with the corresponding method used, in order to reach the study findings (Stage 3); thereby answering the research question. Namely, the first stage starts with explaining the rationale underlying the selection of the adopted PDMs along with defining the characteristics of each, as illustrated in Figure 1 (boxes "a" and "b", respectively). These characteristics reinforced and supported the factors (Figure 1, box "c") that are recognized, through established (in practice and in literature) principles pertaining to the delivery of construction projects under APDMs, to commonly exist and impact the release of design deliverables (e.g. the degree of control/pressure that could be potentially exercised by

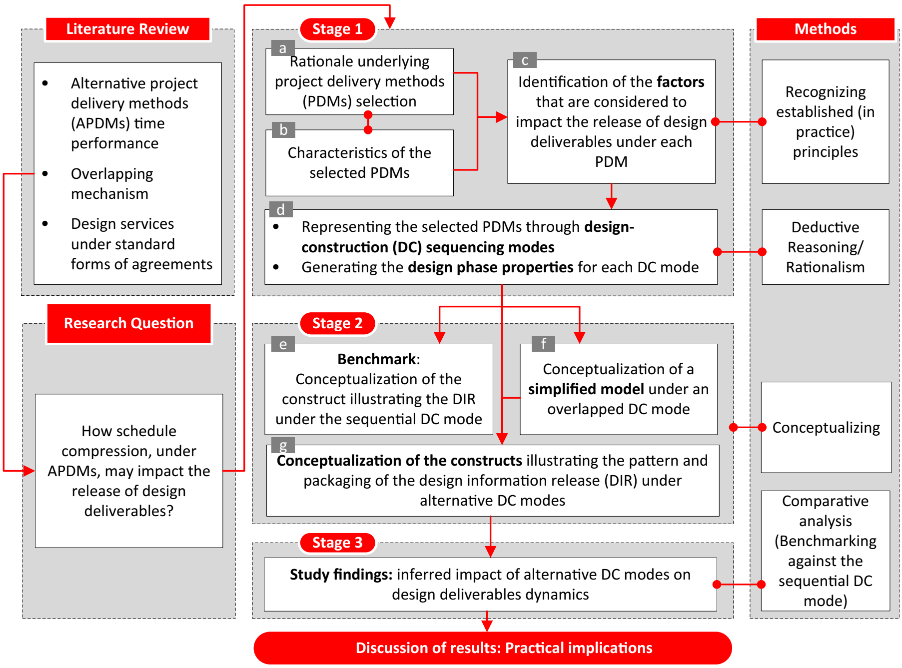


Figure 1.
Research design

the builder). Then, using a deductive reasoning approach the selected PDMs are represented through corresponding DC modes, whereby the respective design phase properties are generated for each (Figure 1, box "d"). This method of rationalism requires that deductions logically rely on clearly stated reasons (in this case the identified factors), or general knowledge (Sargent, 2013; Koskela *et al.*, 2019; Fischer and Gregor, 2011). These identified factors and generated design properties (at Stage 1) informed the conceptualization of the constructs illustrating the dynamics (i.e. the pattern and packaging) of the DIR under each of the identified modes (Stage 2). Namely, the construct illustrating the DIR under the sequential DC mode is first conceptualized (Figure 1, box "e") for benchmark purposes. Then, a simplified model of DIR under an overlapped DC mode is conceptualized (Figure 1, box "f"). This simplified model, along with the identified factors and generated design properties corresponding to each of the alternative DC modes, inform the conceptualization of the alternative constructs (Figure 1, box "g"). Finally, at Stage 3 the study findings are analysed and summarized. *Per se*, a comparative analysis is made through benchmarking the conceptualized alternative constructs against the one pertaining to the sequential DC mode. A detailed description of the work carried out at each stage follows.

Stage 1: Generation of design phase properties under alternative DC modes

Rationale underlying APDMs selection. A project delivery method may be defined as a choice made by owners/developers concerning the pooling of functions (namely, planning, design, construction, operation and finance) along with the possible associated strategies that may be used to deliver a built facility (Kalach *et al.*, 2018a). The pooling defines the basket of responsibilities of a specific team, and the strategies are defined by (1) the timing of involvement of the GC or the construction manager (CM), (2) the concurrency of functions and

(3) the level of participants' integration through the type of contract implemented (Kalach *et al.*, 2018a). The integration of participants covers the full spectrum from the lack of integration using traditional multiple contracts (e.g. DBB) to the full integration of all the key participants under relational contracts (Kalach *et al.*, 2018a). Various combinations result in various delivery methods, each tailored to meet the specific project needs and complexities. Given that collaboration of participants under relational contracts entails a whole different philosophy of financial system transparency and risk sharing in a cooperative and trustful environment (Lahdenperä, 2012), project partnering, project alliancing and integrated project delivery are considered outside the scope of this work. Rather, the main considerations underlying the selection of APDMs form the characteristics that allow these methods to be represented through different DC modes (as contrasted to the sequential mode of the DBB).

To this end, this study is concerned with the following APDMs: (1) the CMAR, (2) the phased DBB with agency construction management (CMa) and (3) the DB. The rational underlying this selection is the early involvement of the general contractor (GC) and the common overlapping of design and construction functions. The phased DBB with CMa (for simplicity purposes, only the acronym CMa will be used in reference to this method) is selected due to the commonly known DC "phasing" (a more detailed description is provided in a following section). Moreover, while several structural variations of the DB method (Beard *et al.*, 2001) exist, the contractor-led approach is selected. The reason is the perceived additional impact related to time pressure, which results out of the "lack of independence" on the part of the A/E professional. Accordingly, throughout the paper, the reference to a DB team is limited to the case of a contracting firm that provides construction services while subcontracting the design-related ones. The characteristics of each of the selected methods are provided in the following sub-sections.

The traditional DBB method

The traditional DBB delivery method is characterized by an owner signing separate agreements with the A/E and the general contractor for design and construction services, respectively (Franz and Leicht, 2016). This separation generates independency between the A/E and the GC and a system of checks and balances (Mahdi and Alreshaid, 2005). Design and construction phases are sequential (Franz and Leicht, 2016). At the end of the design phase, the A/E professional prepares and releases for bidding purposes a single package comprising the complete contract documents (Al Khalil, 2002). Providing owners with a high level of control over the detailed design, the DBB process affords the potential for an optimized design that successfully addresses the owner's requirements (Deshpande *et al.*, 2012). Other characteristics include well-established and clearly defined and documented roles and clear quality standards produced by the complete contract documents (American Institute of Architects-Associated General Contractors of America (AIA–AGC), 2011).

The phased DBB with agency construction management method

The CMa, is otherwise referred to in the literature as the construction management for fee (Ghavamifar and Touran, 2008) or the Construction Manager as Agent method (Lopez Del Puerto *et al.*, 2008). This method involves (1) a CM acting as an agent to the owner for preparing and managing multiple bid packages (in contrast to the single bid package prepared under the DBB), which are phased over time and competitively awarded to trade contractors (in contrast to one GC under the DBB) and (2) an independent A/E for providing design services (Forbes and Ahmed, 2010). The existence of multiple trade contractors removes the single point of responsibility for construction and induces a lack of a guarantee for the overall construction price and completion time (Mahdi and Alreshaid, 2005, Lopez Del Puerto *et al.*, 2008).

The CMAR method

The CMAR delivery method is also known as the CM/GC method (Ghavamifar and Touran, 2008). It is characterized by the same organization chart of the DBB method in that the owner signs separate contracts with the A/E and the GC who is otherwise referred to as a construction manager at risk (CMR) under this method. Unlike DBB, where construction starts after the full completion of design documents, the design in CMAR is released progressively (Antoine *et al.*, 2019). The owner contracts with the CM for pre-construction services. Then, the CM becomes at a later stage the at-risk general contractor, i.e. assuming the risk for the cost and the timely completion of the project (Antoine *et al.*, 2019). Moreover, the CMR assumes the risks of subletting subcontract-related packages (Mahdi and Alreshaid, 2005) and the risk of guaranteeing the completion of the project for a guaranteed maximum price (GMP) based on a partially completed design (The Construction Management Association of America (CMAA), 2012). The CMR is typically engaged on the basis of a cost reimbursable contract (Franz and Leicht, 2016). The CMAR is typically faster than the DBB (Mahdi and Alreshaid, 2005) and the CMa approaches. While the top two advantages of the CM/GC were found to be the design input by the CMR and the ability to fast-track the project and accelerate the project delivery time, the top ranked disadvantage is reported to be in connection with the designer and CMR having different agendas (Shane and Gransberg, 2010). Namely, while contractors are cost-focussed, designers tend to be conservative in their design for the major reason of design liability (Shane and Gransberg, 2010). Moreover, in a CM/GC process, contractors may potentially assume an owner-type role, thereby leading designers to help serve their interests (Farnsworth *et al.*, 2016). This process affords the potential for (1) accelerated start dates, (2) phasing subcontract-related packages and (3) an incremental construction approach characterized by the flexibility of designing a little and building a little (Farnsworth *et al.*, 2016).

The contractor-led design-build method

The DB approach is characterized by having one party responsible towards the owner for design and construction services. Under the contractor-led DB variation, the A/E acts as a design subcontractor under the builder rather than being independent as in the previous PDMs. Design-builders may be engaged either on a lump sum fixed price contract for the completion of all design and construction services, or on a cost-plus contract with the option of a GMP. Typically, LS contracts are implemented (Franz and Leicht, 2016). Design and construction phases are overlapped (Franz and Leicht, 2016; Chen *et al.*, 2016), thereby reducing the overall project delivery time.

Emphasized under the DB method is the builder's considerable control over the sequence of design documents preparation and the related decision-making process (American Bar Association (ABA), 2003), and the inherently dynamic environment (Koch *et al.*, 2010). Under this approach, and as argued by Quatman and Dhar (2003), the CD stage theoretically entails less documentation than other methods "because the design-build team can agree in advance on what drawings, specifications and other documentation are needed", i.e. a less-detailed level of documentation, as a means of reducing the A/E's fees. On the other hand, it could be argued that under the circumstances of having a designer on board, working for the design-builder, the A/E may be involved in any of the construction-related professional services, thereby preparing higher-detailed level of documentation, e.g. shop-drawings or as-built documents. As such, design information under the DB method may be released in different forms depending on the purpose released for, i.e. either suiting the purpose of design progression or suiting the purpose of construction (Kalach *et al.*, 2018b).

Factors impacting the DIR under APDMs. The above reviewed characteristics help in better framing and supporting the three identified factors (as illustrated in Figure 2) that are well-established (in practice) to likely prevail under APDMs. Namely, three factors are recognized to impact the release of design deliverables under APDMs, in contrast to the well-established release under the traditional DBB (which is displayed as the benchmark). These factors correspond to the *intensity of the DC overlap*, the *degree of control/pressure* that may be exercised by the builder on the design process, and the *level of details* in the design documents (i.e. the extent to which the design documents get to be detailed). Starting with the DC overlapping intensity, the earlier the construction starts, the higher the overlapping intensity is likely to be. As such, the overlapping intensity can be thought of to increase when moving from CMa, to CMAR and then to DB. As for the second factor, the higher the pressure a builder may be allowed to exercise over the design progress, in order to meet the construction needs and time-schedule priorities, the higher the degree of control will potentially be. Therefore, the degree of control by the builder increases when moving from the CMAR to the DB method. As for the CMa method, and notwithstanding the lack of control by the builder, the release of bid packages is mainly controlled by the CM's strategy for packaging. Finally, while the level of design documentation details provided under the DBB and CMa methods is commensurate with execution-type drawings (because design deliverables are released for bidding), it becomes mainly dictated by the degree of control that may be exercised by the builder under the CMAR or DB method. That is, the level of details generally decreases under the CMAR due to the builder's early involvement, and even less documentation details may be provided under DB. However, for some deliverables, the required level of details may well increase to the level of shop-drawings.

Design phase properties under each DC mode. In light of the previously reviewed characteristics and identified factors, and following a deductive-reasoning approach, Figure 3 illustrates the representation of each of the methods into its corresponding DC mode, along with the generated design properties. This figure shows two different pooling of functions, either separate or pooled design and construction functions. The former category includes the traditional DBB, the multi-prime approach, the CMAR and the CMa, whereas the latter includes the DB method. That is, for each PDM, the organization chart is displayed along with the contract type and the A/E's status, the DC sequencing mode and the generated design

Project delivery method (PDM)		Factors impacting the design information release (DIR)		
		DC overlapping intensity	Degree of control by the builder	Level of details in the design documents
Benchmark: Traditional PDM	DBB	No overlap	No control	Commensurate with execution-type drawings
Alternative PDMs (APDMs)	CMa	**Increasing**	No control*	Commensurate with execution-type drawings
	CMAR		**Increasing**	**Generally decreasing ****
	DB			

Notes(s): *Notwithstanding the lack of control by the builder, the release of bid packages is mainly controlled by the CM's strategy for packaging
**Notwithstanding that the increased degree of control exercised by the builder generally leads to a reduced level of details in the design documents, the A/E may well be required to provide, for some deliverables, an even higher level of details (i.e., shop-drawings)

Figure 2.
Factors impacting the DIR under each PDM

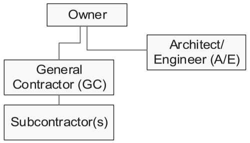
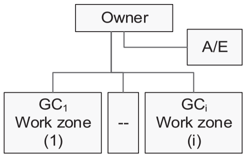
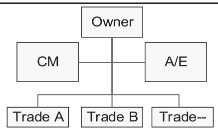
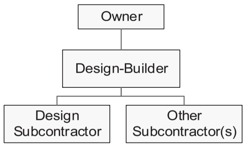
	Organization Chart	Project Delivery Method	Contract	Architect/ Engineer Status	Design and Construction Sequencing	Design Properties: Process	Design Properties: Packaging	Design Properties: Coordination	Design Properties: Purpose of Release
Separate Design and Construction Functions		Traditional DBB	Lump Sum; Unit Price	Independent	Mode 1 Sequential	Sequential Stages	Single One-time Package	Full at Project Level	Tendering Purposes
		Construction Manager at Risk (CMAR)	Cost Plus GMP	Independent	Mode 3 Fast-Track	Concurrent Stages	Successive Release of Design Information Bundles	Partial at Bundle Level	Execution Purposes
		Multi-Prime	Lump Sum; Unit Price	Independent	Mode 1 Sequential	Sequential Stages	Single One-time Package Per Work Zone	Full at Work-Zone Level	Tendering Purposes
			Cost Plus; GMP (≈ CMAR)	Independent	Mode 3 Fast-Track	Concurrent Stages	Successive Release of Design Information Bundles	Partial at Bundle Level	Execution Purposes
		Phased DBB with Agency Construction Management (CMa)	Fixed Fee or % Fee	Independent	Mode 2 Phased	Concurrent Stages	Successive Multiple Packages Per Trade	Partial at Package Level	Tendering Purposes
Pooled Design and Construction Functions		Design-Build (DB)	Lump Sum; Cost Plus GMP	Design Subcontractor	Mode 4 Fast-Track	Concurrent Stages	Gradual Release of Design Information	Variable Levels of Coordination	Satistfying Various Design and Construction Purposes

Figure 3.
Design phase properties under alternative DC modes

properties for each mode. These properties include the *process*, the *packaging*, *coordination* and *purpose of release*.

Given that in a multi-prime approach, multiple GC – potentially overseeing various trades – sign their contracts directly with the owner to build specific work zones of the same project (Gordon, 1994), the delivery of each separate work zone is treated as in a traditional DBB delivery method or CMAR method. Starting with the traditional DBB, this method is represented by DC Mode 1. The corresponding design properties generated for DC Mode 1 are the *sequential* stages of the design process and the *single one-time package,* which is released *for tendering purposes*. Therefore, design coordination is viewed as being *full at the project level*. DC Mode 2 characterizes the *phased* DC sequence of the CMa approach. The design process is inferred to be *concurrent* allowing the *successive multiple packages* per discipline to be released for *tendering purposes*. Design coordination is therefore inferred to be *partial,* due to it being achieved at the package level. DC Mode 3 characterizes the *fast-track* DC sequencing of the CMAR approach. The design process is characterized by the inferred *concurrency or the overlapping* of design stages. As for the packaging of design, it is inferred that *bundles* of design information may be *successively released* for *execution purposes*, i.e. directly for construction, due to the potential control exercised by the CMR over the design process (as synthesized earlier). Therefore, design coordination under this mode is viewed to be *partial*, due to it being achieved at the level of the released bundle of information. As for the last DC Mode 4, the design is driven by the design-builder's schedule and is thus deduced to be released *gradually* in order to allow for an earlier start of the construction process, and an expeditious progression of construction-related activities. The term gradual is used to indicate the more frequent DIR as compared to the previously used "successive release" under DC Mode 3, stemming from the increased degree of control that may potentially be exercised by the design-builder. Design coordination under Mode 4 is conceptualized to vary according to the form of the released information and, therefore, *variable levels of coordination* are inferred to potentially exist. Moreover, the purpose of release is viewed to be *satisfying various design and construction purposes*.

Stage 2: Conceptualization of the constructs

Criteria for construct definition. The above-generated properties of the design phase along with the identified factors impacting the DIR are therefore used as key parameters in conceptualizing the possible alternative dynamics (in terms of pattern and packaging) of the DIR, as compared to traditional mode of release under DC Mode 1. Therefore, the construct of design deliverables dynamics under DC Mode 1 is first illustrated for benchmark purposes, and the possible alternative dynamics are then conceptualized. As subsequently analysed, the inferences are made with respect to the changes in the scope, frequency, and timing of the released deliverables, and – consequently – for the project's design coordination quality, under DC Mode 2, Mode 3 and Mode 4, respectively.

Benchmark: design deliverables release and packaging under DC mode 1. Under the traditional DBB, design and construction phases are sequential, and the design phase evolves *sequentially* from the SD through the DD and ends up at the end of the CD stage, with an increasing level of details and certainty. This sequential DC sequencing is referred to as DC Mode 1 and is considered the benchmark for the DIR. Figure 4 illustrates the construct of design deliverables dynamics under DC Mode 1. Each stage features the design work produced by the multiple disciplines involved and are presented by iterative loops. Moreover, the grey ellipse at the centre indicates the minimum SD work produced by the architecture discipline with few engineering efforts, and which is typically needed for the other disciplines to start their work. At the end of each stage, the set of deliverables is packaged as per the requirements stipulated in the design agreement, for review and approval of the owner.

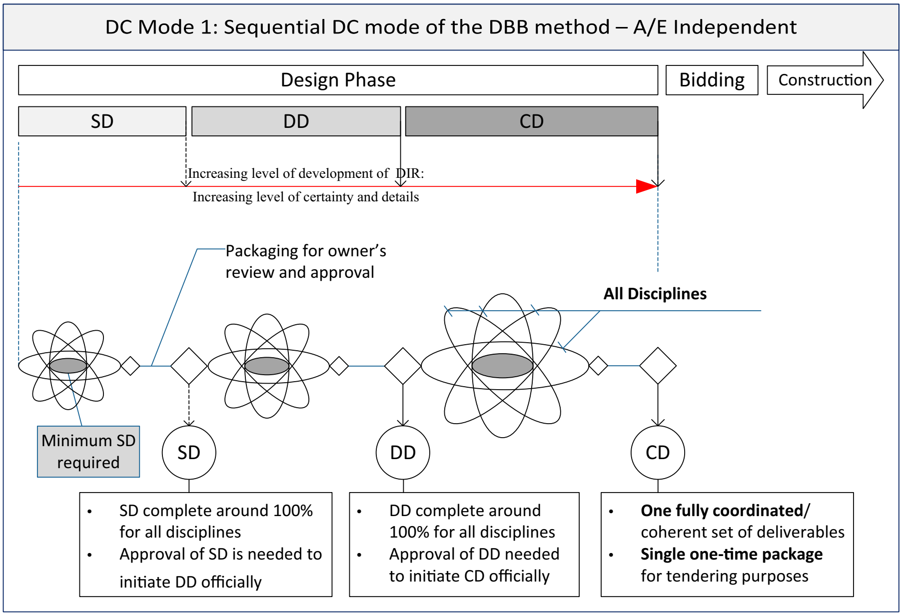


Figure 4.
Construct of design deliverables dynamics under DC mode 1

As such, owner's approval on a set of deliverables at the end of a specific stage officially triggers the start of the following one. Under the DC Mode 1, changes can be made to optimize and improve the design before construction starts. At the end of the CD stage, *one fully coordinated set of deliverables* is *released for tendering purposes*.

Conceptualizing the possible alternative dynamics. In order to conceptualize the possible alternative dynamics (i.e. release pattern and packaging) of the DIR under alternative DC modes, a simplified model (Figure 5) is first presented. The model illustrates the general changes in the DIR under an overlapped DC sequencing. To this end, design and construction phases are shown as overlapped, and design stages are also overlapped as a result of starting construction with a partially completed design. The full duration of each of these design stages is determined according the design stages completion by all the potentially involved design disciplines (e.g. architectural, structural, etc.). Moreover, t_1 refers to how soon the release of design deliverables may start, while t_2 is in reference to how soon the construction phase starts. This indicative model considers two associated disciplines A and B, with Discipline A releasing design deliverables for construction, but after coordinating with Discipline B. The DIR is discussed at the level of one discipline only, the one releasing design documents for construction (i.e. Discipline A).

To this end, the full length of the SD, DD and CD for Discipline A, is designated by SD_A, DD_A and CD_A, respectively. If this discipline is to release only one package, then SD_A, DD_A and CD_A will be carried out sequentially. Therefore, two cases may be encountered: the case of a single package with sequential stages and/or the case of multiple-released packages with overlapping stages, displayed by dotted hatch rectangles and by diagonally-hatched rectangles, respectively. The different coordination levels of the DIR (L_1 to L_6) that emanate from the concurrency taking place are in relation to the degree of design completion in Discipline A and in the associated Discipline B. Moreover, since any information released from an early SD stage is preliminary and matures progressively to become final at the end of the CD stage, an increasing degree of design completion in B reflects an increased certainty of the information

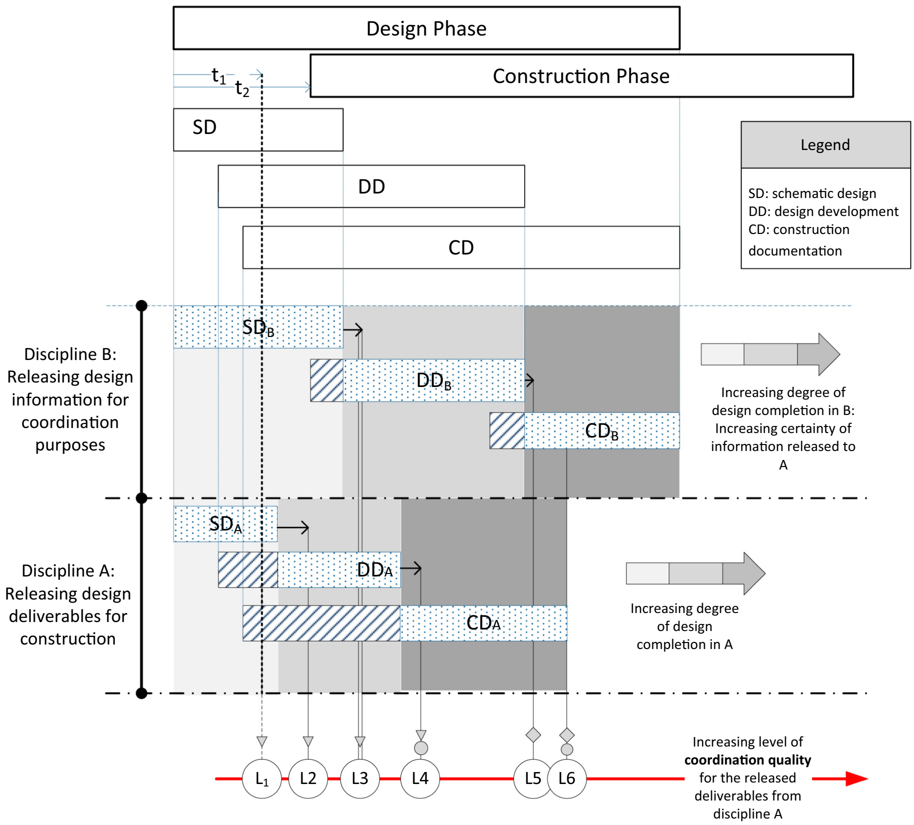


Figure 5.
Simplified model for the alternative dynamics

being coordinated with A. Taking into account that other possible scenarios of the design stages overlap between A and B may also exist, the indicative model in Figure 5 considers the case where DD_A is not finalized unless and until the schematic design stage of B (SD_B) is finalized as well. Moreover, CD_A when finalized, DD_B is displayed as completed as well. Therefore, the DIR from CD_A may appear at six different coordination levels displayed by six different arrow types: (1) released from CD_A and before completion of SD_A (i.e. L_1), (2) released from CD_A having SD_A finalized (i.e. L_2), (3) released from CD_A having SD_A and SD_B finalized (i.e. L_3), (4) released from CD_A having DD_A finalized (i.e. L_4), (5) released from CD_A having DD_A and DD_B finalized (i.e. L_5) and (6) released at the end of CD_A (i.e. L_6). That is, the several packages released for construction (i.e. from the CD stage) are conceptualized to exist at any of these coordination levels. Therefore, the *coordination* attribute of design documentation quality of these packages is defined by the level of coordination that could be afforded to a certain package at the time of being considered for release for construction. This coordination quality is dictated by the degree of design completion in the concerned other disciplines and the respective level of development, i.e. details and certainty, of the information that is the subject of coordination. Therefore, it can be safely deduced that the inferred coordination quality of the released design documents is enhanced when moving from $L_{1,CD}$–$L_{6,CD}$.

Design information release and packaging under DC mode 2. DC Mode 2 characterizes the *phased* DC sequence of the CMa approach. The construct of the DIR in DC Mode 2 (Figure 6)

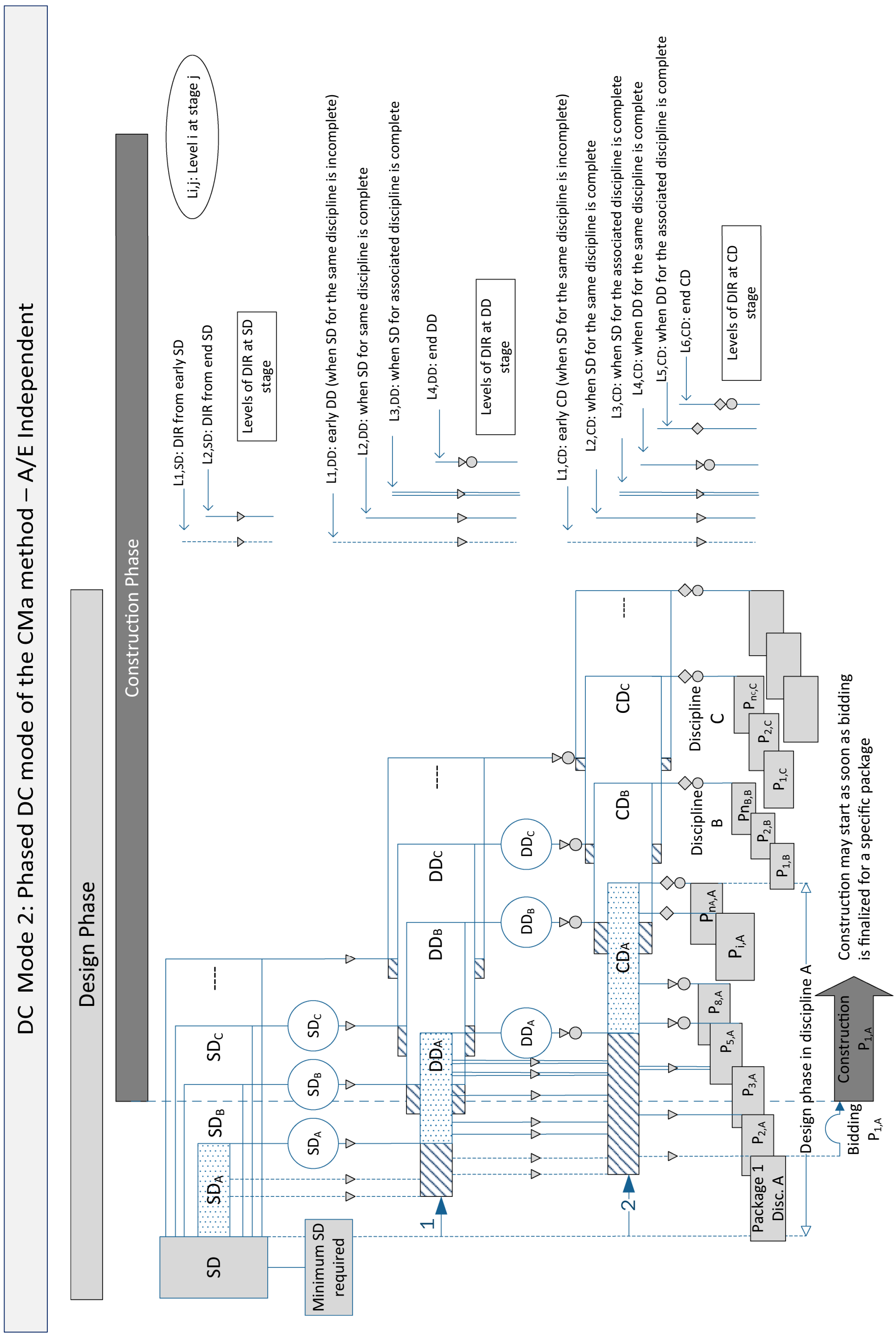


Figure 6.
Construct of design deliverables dynamics under DC mode 2

features *overlapped* design and construction phases and *concurrent SD, DD and CD stages*, but after the completion of enough SD in order to allow for an early launching of bid packages according to the CM's pre-set strategy for packaging. These stages reveal the design work offered by the different involved disciplines/sub-disciplines. These are designated by letters (e.g. A, B) in order to remain indicative and to avoid claiming the precedence of a certain discipline in releasing information for construction. For instance, a closer look at the SD stage features several overlapping boxes with indicative dimensions in order to display the overlap between the disciplines. Evidently, the SD is carried out along many disciplines at the same time.

Thus, if considering the case of multiple released packages, and as soon after the completion of sufficient SD work, including the completion of the SD for the first package in discipline A ($P_{1,\mathrm{A}}$), the DD_{A} may start (corresponding arrow 1). Similarly, as soon after the completion of sufficient DD work, including the completion of the DD for $P_{1,\mathrm{A}}$, the start of the CD stage is triggered (corresponding arrow 2). When CD is completed for $P_{1,\mathrm{A}}$, the first package in discipline A is *released for tendering purposes*. After bidding for this package, construction may start. Therefore, construction is assumed to start when bidding is done for the first completed package, which is translated by the signature of the first trade contract. Typically, under a phased approach, *packages are released on a trade-by-trade basis*, i.e. successively for trade contractors. Similar to the previously illustrated simplified model, the release of design information at the level of each design stage is presented by varying arrow shapes (see legend for these arrow shapes in Figure 6). These arrows are used to indicate the variable coordination levels of DIR.

Regarding the remaining disciplines, successive multiple packages are also presented, with a total number of packages per Discipline n_{D} (D designates the discipline). Emphasized under this mode is that the design packages are released according to the CM's strategy for packaging. The CM does not guarantee completion time; and, therefore, time pressure under this DC mode is expectedly less than the pressure under the fast-track environment of the following Mode 3 and Mode 4. To this end, the packages may be sizeable in order to promote competition and to have more of the good calibre of trade contractors interested in bidding.

Design information release and packaging under DC mode 3. DC Mode 3 characterizes the *fast-track* DC sequencing of the CMAR approach. The design deliverables release under DC Mode 3 is illustrated in Figure 7. While in the previous DC Mode 2 the CM guarantees and promises the owner with the most experienced and professional way in devising the contract packages, the CMR rather guarantees a timely completion.

Under Mode 3, the DIR is driven by the CMR's construction schedule and, therefore, faces the pressure of being released as soon as possible in order to allow the construction works to start and to meet the several deadlines. Inherently, DC Mode 3 features a tougher environment because the production of design information is guided by the construction works deadlines rather than meeting the priorities of the CM's strategy for packaging. As such, the construct of the DIR in Mode 3 differs from the previous construct of Mode 2 in two main aspects, the scope of the released packages and the priorities it serves. Namely, from scope perspective, the bundle of design information that is released by an independent A/E to a CMR entity does not need to abide by the pervious criteria of the CMa method, i.e. having the size of the package attractive for prospective bidders. Therefore, under Mode 3, it is was inferred that DIR will be in the form of *successive bundles of information* instead of packages. Accordingly, the frequency of the DIR per discipline is reasoned to be higher. So, if "n" packages per discipline are released under Mode 2, a higher frequency of release illustrated by "K" bundles per discipline, with narrower intervals, may be released under Mode 3. Therefore, $P_{1,\mathrm{A}}$ (in Mode 2) – theoretically speaking – could be representative of multiple bundles. Evidently, under this approach, the CMR cannot afford to wait for a bigger basket of completed design in order to carry on construction works. Thus, the DD and the CD stages

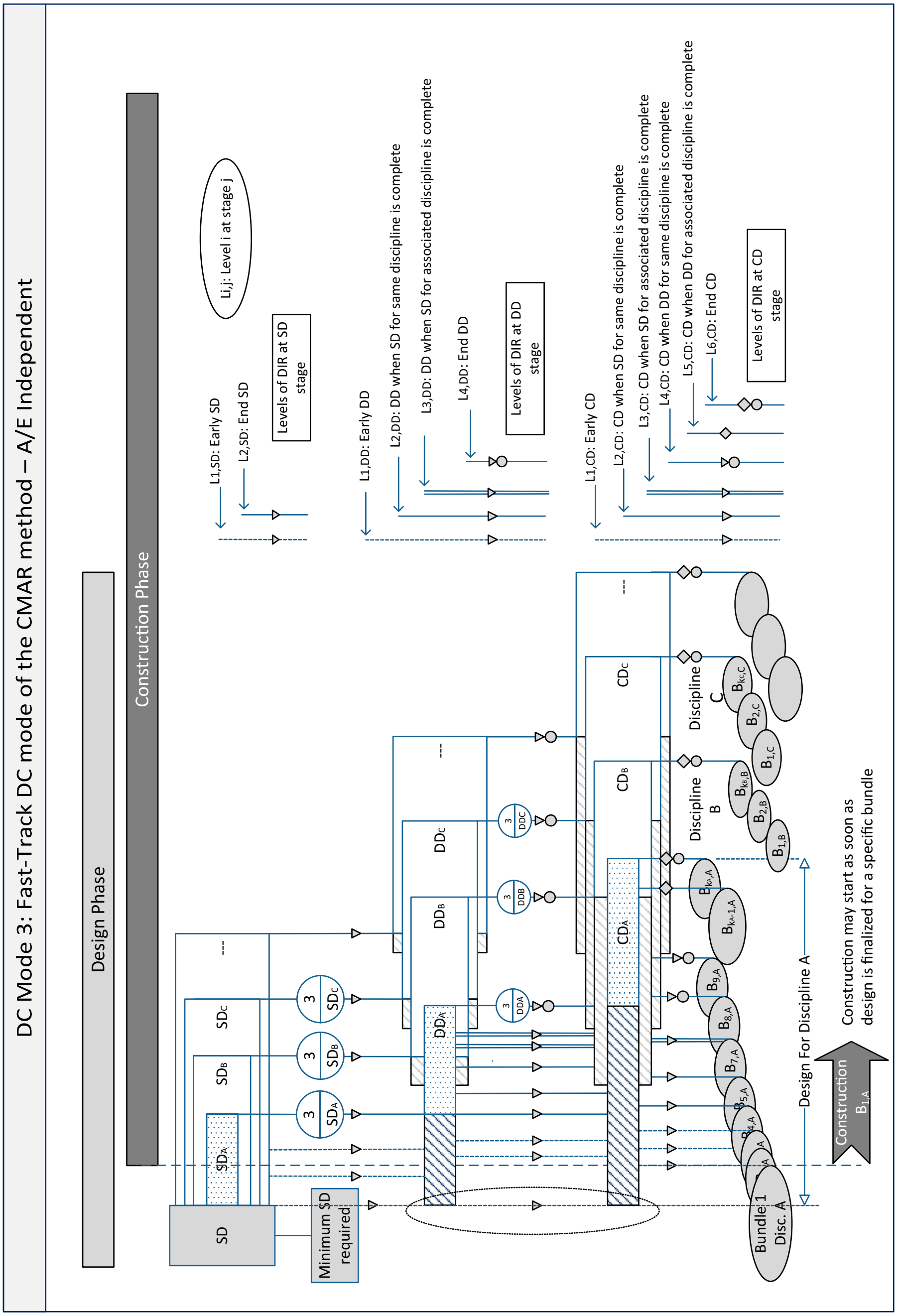


Figure 7.
Construct of design deliverables dynamics under DC mode 3

may theoretically start right after the completion of a minimum SD (illustrated by a dotted ellipse), which is considered to include enough SD work that allows the CMR to price and set the schedule. Further development of the design may be still needed before the guaranteeing of the maximum price and completion time.

As for the coordination levels of DIR, the same logic discussed in the previous Mode 2 applies. But, since the bundles are *released for execution purposes*, there is no bidding phase illustrated (yet, bidding on subcontracting-related packages may well exist), and construction may start as soon as the CD stage of the first bundle of DIR in discipline A ($B_{1,A}$) is completed.

Design information release and packaging under DC mode 4. The DB approach differs from the CMAR in two main criteria; the non-independency of the A/E being rather a design subcontractor under the design-builder and the diffusion of the DD stage which "is often abridged or even eliminated because of growing pressures from compressed schedules and reduced fees" (Quatman and Dhar, 2003). For instance, the AIA's standard form of agreement between the design-builder and the A/E (AIA-B143) (American Institute of Architects (AIA), 2014b) highlights only two stages in the design phase, the preliminary design (PD) and the CD stages. Design work under Mode 4 corresponds to the design carried out at the pre-award of the DB proposal (shown by a grey rectangle in Figure 8), the remaining PD and the CD work. Moreover, the DIR at the end of the PD stage of each discipline is shaded in order to reflect the share of design work by the owner's A/E or otherwise known as the design criteria consultant (DCC) before engaging the design-builder. The DD stage is removed, and the design information released from the PD stage is detailed directly at the CD stage prior to being released for construction. Accordingly, the construction works may start as soon as the first design information is released from discipline A. This could be as soon as the proposal award date or after the elapsing of a lag period necessary to carry additional design work in order to allow the start of the construction work, which is illustrated by the arrow designated by letter "*a*". The indicative scenario illustrated in Figure 8 presents a lag period between the award and the start of construction.

The DIR at the CD stage are displayed at four different coordination levels as shown in Figure 8 (due to the elimination of the DD stage). From scope perspective, these releases are different from the bundles of the previous Mode 3 which are produced by an independent A/E. Moreover, it is assumed that, if "n" packages per discipline may be released under Mode 2, and "k" (greater than n) bundles per discipline may be released under Mode 3, then "l" (l could be even greater than k) releases may be released under Mode 4. Compared to Mode 3, a higher frequency of release is expected under Mode 4.

Stage 3: Study findings

This study aims at investigating how alternative DC modes, under APDMs, may impact the dynamics of the released deliverables. By benchmarking against the construct illustrating the DIR under the sequential DC mode of the DBB method (i.e. DC Mode 1), a comparative analysis was performed in order to infer the findings of the study, as summarized in Figure 9. Namely, the findings revealed that in contrast to the traditional one-time packaging of design deliverables, multiple DIR – with less certainty on their scope, timing, frequency and coordination quality – are released under alternative DC modes. This uncertainty mainly emanates from the deduced impact of the identified factors (e.g. DC overlapping intensity and degree of pressure by the builder) on the design deliverables dynamics. Whether guided by the CM's strategy for packaging under DC Mode 2 or by the builder's schedule in Mode 3 and 4, the resultant reduced degree of control retained by the A/E over the released information dictates the extent to which design work is driven by the construction needs. That is,

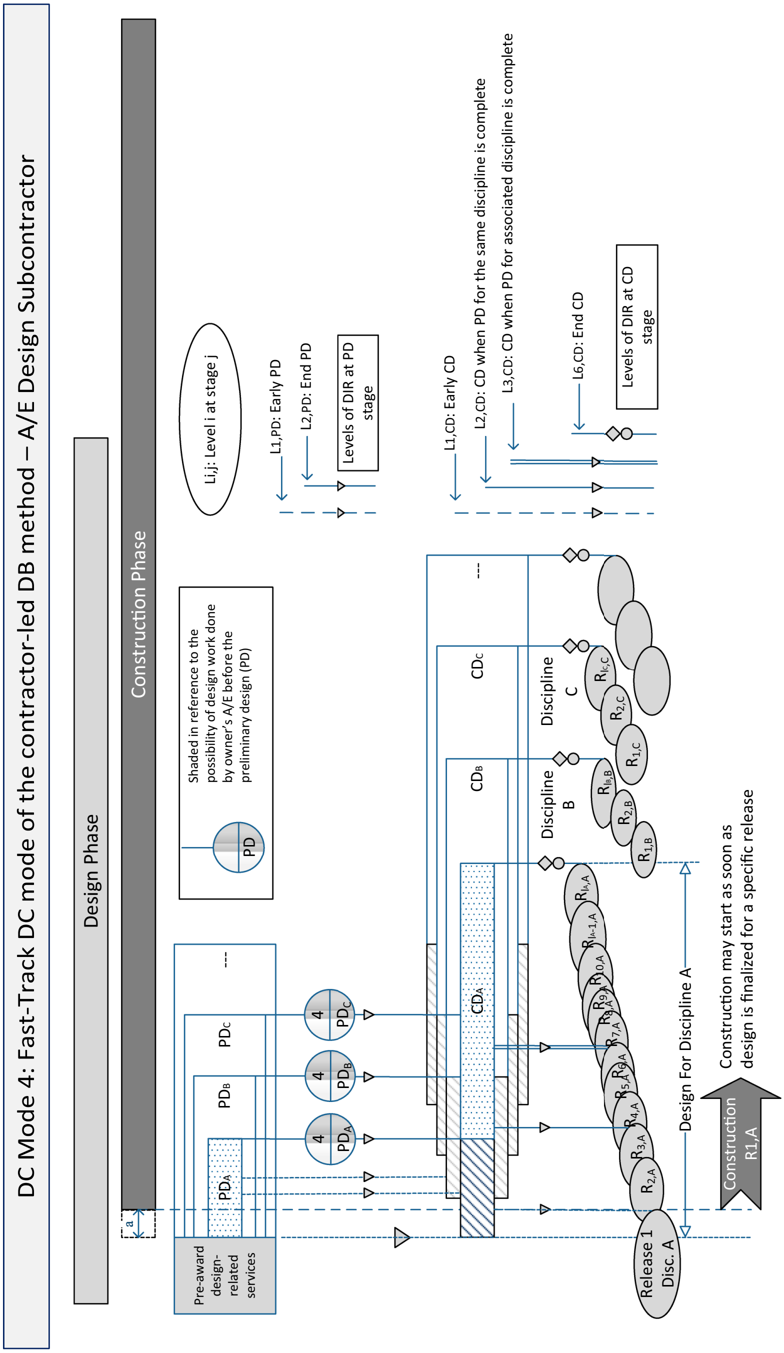


Figure 8.
Construct of design deliverables dynamics under DC mode 4

Design-Construction (DC) Sequencing Mode		Inferred Design Information Release (DIR) Dynamics			Inferred Project's Design Coordination Quality
		Number	Scope	Frequency	
Benchmark: Sequential DC mode	DC Mode 1	One package	Full scope	One-time	Theoretically fully coordinated set of deliverables
Alternative DC modes	DC Mode 2	**Potentially increasing**	**Potentially decreasing**	**Potentially increasing**	**Potentially decreasing**
	DC Mode 3				
	DC Mode 4				

Figure 9.
Summary of study findings

(1) An increased time pressure on the A/E when moving from DC Mode 2 through Mode 3 to Mode 4, is translated by the *scope* of the DIR, the priority being served and the increased *frequency* of release.

(2) DC Mode 3 features a tougher environment than DC Mode 2 because the production of design information is guided by the construction work's deadlines rather than meeting the priorities of the CM's strategy for packaging.

(3) When it comes to DC Mode 4, the releases are different from the bundles of Mode 3 which are produced by an independent A/E.

As such, if the same project is to be delivered using any of the illustrated DC modes, then the deduced changes in the DIR dynamics (as compared to the DC Mode 1 benchmark) are illustrated in Figure 9. Namely, when moving from DC Mode 2 through DC Mode 3 to DC Mode 4:

(1) The number of released deliverables is inferred to increase with an inherently reduced scope (due to the evident splitting of the full scope of the project's design) and an increased frequency of DIR.

(2) Accordingly, the project's design coordination quality is deduced to potentially decrease from DC Mode 2 through DC Mode 3 to DC Mode 4.

Discussions: practical implications

Design documentation quality-related implications

In the traditional DC Mode 1, the single-package type of DIR and the respective theoretical full coordination at the project level give rise to an enhanced coordination quality for the released deliverables. Therefore, the risk of rework caused by coordination quality-related deficiencies can be argued to be kept to some inevitably minimum level. Inherent with the alternative DC modes is the added reason for encountering rework due to the concurrency taking place and the use of early information. However, the above-conceptualized constructs help inferring that rework is due to (1) the inability to afford the potential for a complete and compatible coordination for the DIR or (2) sub-optimally detailed releases for the purpose of construction, as in the DC Mode 4 of the DB approach. The former case mainly stems from the incompatible design stages between the components of the release and the several associated design elements that are yet to be released, while the latter one results from the lack of an owner's review requirement preceding construction, combined with the non-independency of the A/E who is therefore afforded less control over the required detail level for the DIR.

Moreover, under alternative DC modes, the *coordination* attribute of the design documents quality, as discussed in this study, is the result of having the released information at any of the previously discussed levels spanning from L_1 to L_6. This documentation quality-related attribute is dictated by the time-variant degree of design completion of the concerned other disciplines. However, the several possible alternative dynamics of the DIR under alternative DC modes influence the possible number of design packages that may be released at each of the identified levels. For instance, an aggressive schedule compression, characterized by a higher intensity of overlap and an increased pressure by the builder, leads to an increased number of packages released at L_1 and L_2 coordination levels (for instance), as opposed to higher ones. Therefore, the aspired advantages of schedule compression – when opting for alternative DC modes – may be offset (at least partially) by a compromised documentation quality, and an increased error-prone performance of the released deliverables is therefore more likely to be encountered. While short-term risks are translated with a higher frequency of rework emanating from the incompatible coordination taking place, long-term risks may also prevail. For instance, designers, design review professionals and project owners must be aware that any reduced certainty on the design documentation quality must be assessed against a potentially increased exposure to liabilities for design errors and omissions. Moreover, the higher the overlapping intensity is, and when coupled with improper planning and inadequate design management, the higher the risks are of an inferior design quality (e.g. increased life-cycle cost performance). Here comes the benefit of collaboration to the project delivery process, whereby management efforts can be directed towards improving the total project performance rather than focussing on meeting specific design or construction priorities. While such an approach aligns with the lean philosophy to project delivery, incrementally applying lean techniques throughout the delivery process of construction projects is argued to render promising results (Wodalski *et al.*, 2011).

The A/E role-related implications

Under the traditional DC Mode 1 standard forms of agreement present a wide base of commonalities as to how design stages are structured throughout the design process. These stages offer a systematic and well-established A/E's role in rendering design deliverables and are observed as important milestones in the design process. In contrast, under the considered alternative DC modes, design deliverables are either phased for specific trades with respect to a CM's best strategy for packaging or released according to the builder's schedule that better serves meeting deadlines and construction priorities. Therefore, the increased uncertainty associated with the timing, frequency and scope of the released deliverables can be inferred to cause unclear expectations concerning the planning for the A/E's needed resource staffing. As the construct of design deliverables dynamics under Mode 4 features the highest frequency of release and two vital distinct parameters, i.e. the "non-independency" of the A/E and the diffusion of the DD stage, Figure 10 shows the inferred implications of DC Mode 4 on the formation of design teams.

The level of work produced by the different design team members, as illustrated at the top of Figure 10, is inspired from the work of Gray and Hughes (2001) whereby the most senior staff members are presented in the top of a pyramid, delegating work to their subordinates, and managing their work. In other words, design solutions are (1) worked out by the senior level (SL) staff at the SD stage (at the top of the pyramid) (2) broken down into components that are resolved by the middle-level (ML) staff at the DD stage and (3) detailed through the lowest level junior-level (JL) staff at the CD stage. As such, the staffing needed by the A/E is

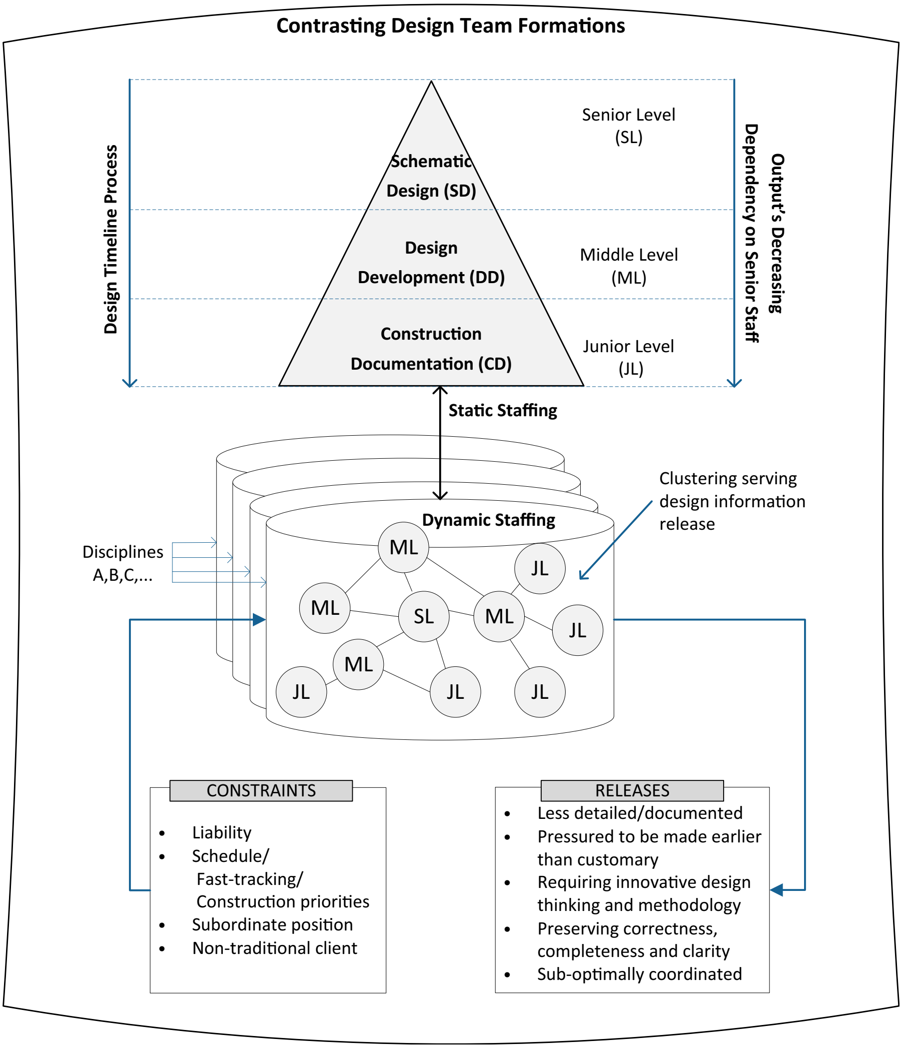


Figure 10.
Design team staffing requirement under DC mode 4

conceptualized to change from the traditionally static staffing, i.e. as displayed by the decreasing dependency on senior staff as the output of design progresses from the SD towards the CD stage, to a more dynamic one illustrated by team clusters under Mode 4. This dynamic staffing is theorized to serve the specific DIR. Consequently, the needed combination of SL, ML or JL type of staff in each design discipline, at any period in the design phase, depends on the nature of the release taking place. Coupled with the pressure of schedule compression, the DIR is constrained by the burden of the design liability. Consequently, the release of design deliverables (Figure 10) is illustrated as being constrained by several issues. These include, design liability, schedule/fast-tracking/construction priorities and working in a subordinate position to a non-traditional client in contrast to its long-standing leadership position. Therefore, to balance the effort made in producing the deliverables with the constraints inherent with the DB method, the produced documents which are conceptualized to be less detailed/ documented and pressured to be made earlier, need to be concise with a clear and careful documentation. As such, the A/E is required to be more innovative in the design thinking/methodology and this could be achieved by incorporating more practical design solutions.

Study validation

Given the nature of this study, face and content validity were selected as the most appropriate non-statistical validation techniques (Lucko and Rojas, 2010; Sargent, 2013). To secure face validity of the research endeavour, in a practical field such as the construction engineering and management, the appropriate approach is through interviewing industry practitioners and seeking their opinion regarding the correctness of the study's underlying logic, and the soundness of the input–output relationships (Sargent, 2013). If the content of a study is found to fairly reflect the reality, content validity is satisfied as well (Lucko and Rojas, 2010). To this end, the authors adopted a purposive sampling and performed semi-structured interviews with five industry practitioners from the top two consulting firms in the Middle East and North Africa region (one of which is ranked as top #6 worldwide, and the other firm is ranked as top #46, according to the Engineering News Record). The distribution of the practitioners is as follows: three professionals (one architect, one structural engineer and one mechanical engineer, with 31, 17 and 12 years of experience, respectively) working in the top #46 worldwide design firm, one structural engineer with 18 years of experience working in the top #6 design firm, and one structural engineer with 19 years of experience working as a freelancer design consultant for many design firms. These experts were selected owing to their experience in traditional and alternative project delivery methods. While the main purpose of the interviews was to seek the experts' opinions with respect to five tracks, i.e. (1) the validity of the identified factors at Stage 1, (2) the validity of the generated design properties for each DC mode (Stage 2), (3) the degree to which the conceptualized constructs reflect the DIR dynamics under each DC mode, (4) the validity of the findings and (5) the work practical implications, the interviewees had the flexibility to express their opinion and give their reflections based on their own experience.

As for the three identified factors (Stage 1), the consensus of the experts was not only on the identified factors to actually exist but also on the degree of prevalence of such factors under APDMs and on the highly experienced impact they have on the DIR. Namely, the high degree of control that may be exercised by the design-builder on the A/E was said to be "*actually translated by having representatives sent by the design-builder to our offices to rush the release of design deliverables and make sure that their requests are indeed our top priorities.*" This was reported by one of the experts who also recognized the variable level of details that would be normally expected under a DB method or a CMAR approach (as reflected by the double asterisks in Figure 2). Namely, while a reduced level of details is commonly expected due to the builder's early involvement, a shop-drawing level detail may well be required as well. However, an interesting statement by one of the experts was to the effect that he would rather favour the extreme pressure exercised by the builder under the DB method over the very lengthy process of the DBB one, indicating: "*in DB we face extreme pressure, yet we know that all coordination issues are resolved with the same people involved and within a shorter schedule; however, in DBB, when construction starts and problems start to surface out of some missing information or due to constructability problems, we may not have the same team that was previously involved in the design, and it is always unfavourable for designers to re-visit previously submitted projects.*"

When it comes to the generated design properties, the conceptualized constructs and the study findings, these were considered as being the very normal and logical consequence of the previously identified factors. However, one of the experts commented that the increased frequency of DIR may sometimes increase the chances to discover errors earlier. In contrast, another opinion was that "*any reduced time allocation for a certain design task, when coupled with the concurrency between design and construction, and no matter how complete the afforded coordination may be for a released package, the increased number of releases and the splitting of the full scope into smaller ones, would normally be at the extent of the design coordination of the project as a whole.*"

Finally, towards the end of each interview, the interviewed professional was asked whether he/she perceives any changes in the dynamics of the DIR or in the respective implications with respect to the project type. The consensus was that the conceptualized constructs for the DIR under alternative DC modes along with the reasoning and inferences made throughout the previous stages are valid for any type of construction project. The project type (e.g. buildings, roads, airports, etc.) rather dictates the number of disciplines involved, the interdependency between them, and the primacy of a certain discipline in starting the release of design deliverables. However, the other factors that were perceived as impacting the dynamics of the DIR were instead: (1) the number of design firms involved, whether one firm is providing all services in house or having multiple firms involved, and whether these are local or international and (2) the time of involvement of the several disciplines involved when these were under different firms. Moreover, some external factors, e.g. the prevailing laws with respect to the issuance of permits and the required approval by authorities, were also seen as impacting the DIR.

Conclusion

Alternative project delivery methods allow for a compressed project delivery time. The potential timesaving advantage is mainly attributed to the earlier involvement of the builder and to the common practice of DC overlap. Scholars commonly use the term fast-track project delivery interchangeably with APDM, reflecting a general case of DC or design-design being overlapped, irrespective of the characteristics of the APDM in place. Namely, literature works addressing the overlapping/fast-tracking mechanism in construction projects were not applied in the context of a specific APDM and were mainly concerned with gaining maximum advantages of this mechanism. However, the impact of fast-tracking on the dynamics of the design deliverables was not previously addressed.

The contribution of this work lies in offering a novel study that theorizes the impact of time-reduction related factors, under alternative design and construction modes, on the release of design deliverables, then providing discussions with respect to the implications of such a hypothesized alternative dynamics of the DIR on the design documentation quality and on the planning for the A/E's needed resource staffing. That is, this study argues that various DC modes may exist depending on the characteristics of each delivery method, with each entailing different design phase properties and, respectively, different DIR dynamics. To this end, three alternative DC modes corresponding to the CMa, the CMAR and the DB method were identified, and the possible alternative DIR dynamics were conceptualized under each. It was inferred that delivering construction projects using the sequential DC Mode 1 of the DBB delivery method can be said to afford a compatible coordination for the various design elements due to the one-time packaging of design deliverables, thereby allowing a full coordination at the project level to be performed. By benchmarking against DC Mode 1, alternative DC modes were found to potentially lead to less certainty as to the scope, timing, frequency and coordination quality of their associated releases of design deliverables. This uncertainty mainly emanates from starting construction activities with partially completed design and having design activities potentially driven by the builder's schedule and related priorities. More uncertainty may prevail when the A/E ends up rendering the contracted deliverables as a design subcontractor, in DC Mode 4. As such, it was possible to infer that the potential advantages of schedule compression – when opting for alternative DC modes – may contribute to causing a compromise in respect of the quality of released design documentation, thereby increasing the likelihood of such deliverables to be prone to being in error. Namely, the risk emanates from the uncertainty associated with the release of deliverables at any of the displayed levels of incompatible coordination, as illustrated in the conceptualized DIR constructs. However, the several possible alternative dynamics of the DIR under alternative DC modes, influence the possible number of design packages that may be released at each of the identified levels.

This study shall be of benefit to A/E professionals as well as to project owners in better planning for their roles and responsibilities under each of the identified modes, as it helps raising their awareness on new issues brought about by APDMs. For instance, the presented analysis indirectly informs designers, design review professionals and project owners about a potentially increased liability exposure emanating from the reduced certainty on the DIR's coordination quality. Moreover, the presented analysis suggests that a design team's re-formation and/or re-structuring (i.e. of the involved staff) may need to be configured, in order to accommodate the emphasized dynamism and circumstances governing the release of design deliverables under alternative DC modes. A limitation of this study is that the conceptualized dynamics are not data driven. However, the conceptual constructs provide the theoretical baseline for comparing the alternative dynamics of the released deliverables and the respective implications. Future work can look at examining the impact of such dynamics on the frequency of encountering design and construction rework and the resulting quality of the built facility.

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